

CLAIMS

What is claimed is:

1 1. (currently amended) A method of determining a parameter of interest for a region of an
2 earth formation using a nuclear magnetic resonance (NMR) instrument conveyed
3 in a borehole, the method comprising:

- 4 (a) producing a static magnetic field in ~~a region including~~ said region of
5 interest;
6 (b) transmitting a sequence of radio frequency (RF) pulses ~~for~~ and producing
7 an RF magnetic field in said region, said RF magnetic field having a
8 spatially varying intensity in said region ~~and a direction substantially~~
9 ~~orthogonal to a direction of said static magnetic field, a subset at least one~~
10 of said RF pulses ~~further~~ having a pulse length related to ~~zeros~~ a zero of a
11 Bessel function;
12 (c) receiving NMR signals ~~having amplitudes~~ produced by said RF magnetic
13 field; and
14 (d) determining said parameter of interest using said ~~amplitudes received~~
15 NMR signals.

16
1 2. (currently amended) The method of claim 1 wherein said said parameter of interest
2 comprises at least one of (i) a spin density function, (ii) porosity, (iii) fluid
3 content, (iv) permeability, (v) longitudinal relaxation time, and, (vi) transverse

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4 relaxation time.

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1 3. (currently amended) The method of claim 1 wherein said NMR signals comprise free
2 induction decay signals ~~associated with said subset of RF pulses.~~

3

1 4. (currently amended) The method of claim 1 wherein said ~~subset of~~ sequence of RF
2 pulses comprises tipping pulses, ~~the pulse sequence further comprising a plurality~~
3 ~~of and~~ refocusing pulses associated with said tipping pulses, and wherein said
4 NMR signals comprise spin echo signals.

5

1 5. (currently amended) The method of claim 3 wherein determining said parameter of
2 interest further comprises performing an inverse Hankel transform on said NMR
3 signals.

4

1 6. (currently amended) The method of claim 5 wherein determining said parameter of
2 interest further comprises using a spatial mapping to map ~~said~~ a spin density to a
3 spatial location.

4

1 7. (currently amended) The method of claim 4 wherein said ~~sequences~~ sequence of RF
2 pulses ~~are~~ is of the form:

3
$$[\tau_j - \frac{TE}{2} - (R - TE)_i - TW]_j$$

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4 where TE is a time interval between refocusing pulses R, τ_j is a tipping pulse, TW
5 is a wait time, i is the index of the number of refocusing pulses, and j is the index
6 of the number of CPMG (or modified CPMG) sequence acquired for a single
7 tipping pulse.

8

1 8. (original) The method of claim 7 wherein determining said parameter of interest further
2 comprises summing the spin echo signals resulting from said sequence of RF
3 pulses over the index j for a selected value of i .

4

1 9. (original) The method of claim 8 wherein said summing is a weighted summing.

2

1 10. (currently amended) The method of claim 9 wherein determining said parameter of
2 interest further comprises using a spatial mapping to map said a spin density to a
3 spatial location.

4

1 11. (currently amended) The method of claim 6 further comprising determining spins
2 associated with a portion of the region ~~of interest~~ outside said borehole.

3

1 12. (original) The method of claim 10 further comprising determining spins associated
2 with a portion of the region outside said borehole.

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1 13. (currently amended)The method of claim 6 further comprising partitioning said spins
2 into azimuthal sectors.
3

1 14. (currently amended)The method of claim 10 further comprising partitioning said spins
2 into azimuthal sectors.
3

1 15. (original)The method of claim 1 further comprising repeating (a) – (d) for a number of
2 different azimuthal orientations of said instrument.
3

1 16. (currently amended)The method of claim 15 further conveying said NMR instrument
2 into said borehole on a bottom hole assembly.
3

1 17. (currently amended)An apparatus for determining a parameter of interest ~~for~~ of a
2 region of an earth formation comprising:

3 (a) a magnet ~~for~~ producing a static magnetic field ~~having a direction~~ within
4 the region;

5 (b) a transmitter ~~for~~ transmitting a sequence of radio frequency (RF) pulses ~~for~~
6 and generating a RF magnetic field in said region, said RF magnetic field
7 having a spatially-varying intensity in said region ~~and a direction~~
8 ~~substantially orthogonal to the direction of the static magnetic field,~~

9 (c) a processor ~~for~~ controlling said transmitter and defining a ~~subset~~ at least

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- 10 one of said RF pulses to have a pulse lengths length related to ~~zeros~~ a zero
- 11 of a Bessel function;
- 12 (d) a receiver for receiving NMR signals produced by said RF magnetic field;
- 13 and
- 14 (e) a processor for determining said parameter of interest from ~~amplitudes of~~
- 15 said NMR signals.

16

- 1 18. (currently amended) The apparatus of claim 17 wherein said said parameter of interest
- 2 comprises at least one of (i) a spin density function, (ii) porosity, (iii) fluid
- 3 content, (iv) permeability, (v) longitudinal relaxation time, and, (vi) transverse
- 4 relaxation time.

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- 1 19. (currently amended) The apparatus of claim 17 wherein said NMR signals comprise
- 2 free induction decay signals ~~associated with said subset of RF pulses.~~

3

- 1 20. (currently amended) The apparatus of claim 17 wherein sequence of pulses of said
- 2 ~~subset of RF pulses are~~ comprise tipping pulses; ~~the pulse sequence further~~
- 3 ~~comprising a plurality of~~ and refocusing pulses ~~associated said tipping pulses and~~
- 4 wherein said NMR signals comprise spin echo signals.

5

- 1 21. (original) The apparatus of claim 17 wherein said processor in (e) is configured so as

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2 to determine a spin density as a function of said RF field intensity.

3

1 22. (original) The apparatus of claim 21 wherein said processor is configured to transform
2 said spin density to a spatial location.

3

1 23. (currently amended) The apparatus of claim 21 wherein said ~~sequences~~ sequence of
2 RF pulses are is of the form:

3
$$[\tau_j - \frac{TE}{2} - (R - TE)_i - TW]_j$$

4 where TE is a time interval between refocusing pulses R, τ_j is a tipping pulse, TW
5 is a wait time, i is the index of the number of refocusing pulses and j is the index
6 of the number of CPMG (or modified CPMG) sequence acquired for a single
7 tipping pulse.

8

1 24. (currently amended) The apparatus of claim 17 wherein the same antenna is used
2 for transmitting said RF pulses and receiving said NMR signals.

3

1 25. (original)The apparatus of claim 17 wherein said processor in (c) and said processor
2 in (e) are the same.

3

1 26. (new) The method of claim 1 wherein said Bessel function is a Bessel function of
2 zero order and first kind.

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3

1 27. (new) The apparatus of claim 17 wherein said Bessel function is a Bessel function of
2 zero order and first kind.

3

1 28. (new) A method of composing a radio frequency (RF) pulse sequence for use in a
2 nuclear magnetic resonance (NMR) apparatus, the method comprising:
3 (a) defining a length of at least one pulse of the RF pulse sequence based on a
4 zero of a Bessel function;
5 (b) producing a RF field with said RF pulse sequence; and
6 (c) analyzing NMR signals resulting from the produced RF field.

7

1 29. (new) The method of claim 28 wherein said Bessel function is a zero order Bessel
2 function of the first kind.

3

1 30. (new) A nuclear magnetic resonance (NMR) apparatus comprising:
2 (a) a processor that:
3 (i) defines a length of at least one pulse of a radio frequency
4 RF pulse sequence based on a zero of a Bessel function, and
5 (ii) pulses a transmitter with the RF pulse sequence,
6 wherein the transmitter produces a RF field;
7 (b) a receiver which receives NMR signals resulting from the RF field;

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8 (c) a processor which analyzes the received NMR signals.

9

1 31. (new) The NMR apparatus of claim 30 wherein the Bessel function is a Bessel

2 function of zero order and the first kind.

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